

# Multi-Resolution Analysis of MODIS and ASTER Satellite Data for Water Classification

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## ABSTRACT

*Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) are multi-spectral sensors embarked on the EOS AM-1 (TERRA) satellite platform. Both sensors operate in different spectral bands, but also with different pixel resolutions.*

*The overall goal of this paper is to classify MODIS data to get an estimation of water surface area, very useful in the post-crisis periods for the decision makers at all levels.*

*To develop the classification technique, the strategy was to obtain MODIS and ASTER data acquired at the same time over the same location, and use the ASTER data as “ground truth”. Two lakes in the Bihor County of Romania were chosen and satellite data from October 31, 2002 were utilized. From the ASTER data we created a detailed water mask to be used as ground truth for the MODIS water classification. The percent water image derived from ASTER was superimposed on the MODIS image. A supervised classification for water was performed on the 3-band MODIS image using the feature space algorithm. The water surface area as measured from the MODIS classification was about 16% more than the ASTER ground truth-value. Due to the constraint that high spatial resolution satellite images are low temporal resolution, there exists a need for a reliable method to obtain accurate information from medium resolution data.*

*This approach provided useful information concerning the water classification from different resolution data that could help in the estimation of water surface area from MODIS imagery.*

## 1.0 INTRODUCTION

Flooding events are quite common in Romania. The estimation of the surfaces covered by water in the post-crisis periods is of real use for the decision makers at all levels. The classification problem of water cover surfaces from satellite images was approached in many applications. Even a binary classification of satellite images from optical domain seems to be simple enough comparing with a multi-class classification. But there exists many other constraints. The cloud cover in the flood time is important and the spectral characteristics of water while and after floods are quite different from the clear water and it is difficult to distinguish. Another difficulty in water surfaces estimation is represented by the ground

Alecu, C.; Oancea, S.; Bryant, E. (2006) Multi-Resolution Analysis of MODIS and ASTER Satellite Data for Water Classification. In *Emerging and Future Technologies for Space Based Operations Support to NATO Military Operations* (pp. P2-1 – P2-8). Meeting Proceedings RTO-MP-RTB-SPSM-001, Poster 2. Neuilly-sur-Seine, France: RTO. Available from: <http://www.rto.nato.int/abstracts.asp>.

<b>Report Documentation Page</b>			Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>01 DEC 2006</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED <b>-</b>		
<b>4. TITLE AND SUBTITLE</b> <b>Multi-Resolution Analysis of MODIS and ASTER Satellite Data for Water Classification</b>			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
<b>6. AUTHOR(S)</b>			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> <b>National Meteorological Administration (NMA) 97 Soseaua Bucuresti-Ploiesti, Sector 1, 013686 Bucharest Romania</b>			8. PERFORMING ORGANIZATION REPORT NUMBER	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
<b>12. DISTRIBUTION/AVAILABILITY STATEMENT</b> <b>Approved for public release, distribution unlimited</b>				
<b>13. SUPPLEMENTARY NOTES</b> <b>See also ADM202419. The original document contains color images.</b>				
<b>14. ABSTRACT</b>				
<b>15. SUBJECT TERMS</b>				
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b> <b>UU</b>	
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	<b>18. NUMBER OF PAGES</b> <b>8</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>

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resolution of the pixel in the satellite image. In the case of high-resolution sensors (ASTER, SPOT/XS, LANDSAT-TM, IRS), the water separation is simpler than in the case of medium resolution satellites (MODIS, NOAA/AVHRR). This is related to the pixel resolution (250-500 m for visible bands for MODIS, 1.1 km for NOAA/AVHRR images). The water could exist only on a part of the pixel surface but the signal coming from that pixel indicates water for the entire surface of that pixel. This may result into an under or over-estimation of the total water surface. Due to the constraint that high spatial resolution satellite images are low temporal resolution, one needs a reliable method to obtain accurate information from medium resolution data.

MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Both sensors are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands.

The ASTER instrument is embarked only on the Terra satellite and consists of three separate instrument subsystems, operating in a different spectral region: the Visible and Near Infrared (VNIR), the Short wave Infrared (SWIR), and the Thermal Infrared (TIR). In the table 1 are presented some of the spectral bands of the ASTER and MODIS sensors.

MODIS data have the potential for flood monitoring due to their high time resolution and low cost, with the constraint that the cloud-free images are quite rare during flood periods. Taking into consideration the spectral characteristics of the main ground-cover types during floods and satellite signal components, this paper discusses the comparison between MODIS and ASTER water classification. The methodology was to approximate the fraction that is water, so we can estimate the on-the-ground surface water area in MODIS images, on the basis of ASTER data as ground-truth.

**Table 1 - The characteristics of ASTER first 9 spectral bands (left) and of MODIS first 7 spectral bands (right)**

Spectral bands		Spectral Range	Ground Resolution	Spectral bands	Spectral Range	Ground Resolution
VNIR	1	Band 1: 520 - 600 nm Nadir looking	15 m	1	620 – 670 nm	250 m
	2	Band 2: 630 - 690 nm Nadir looking		2	841 – 876 nm	250 m
	3N	Band 3: 760 - 860 nm Nadir looking		3	459 – 479 nm	500 m
	3B	Band 3: 760 - 860 nm Backward looking		4	545 – 565 nm	500 m
SWIR	4	Band 4: 1600 - 1700 nm	500 m	5	1230 – 1250 nm	500 m
	5	Band 5: 2145 - 2185 nm		6	1628 – 1652 nm	500 m
	6	Band 6: 2185 - 2225 nm		7	2105 – 2155 nm	500 m
	7	Band 7: 2235 - 2285 nm				
	8	Band 8: 2295 - 2365 nm				
	9	Band 9: 2360 - 2430 nm				

## 2.0 METHODOLOGY

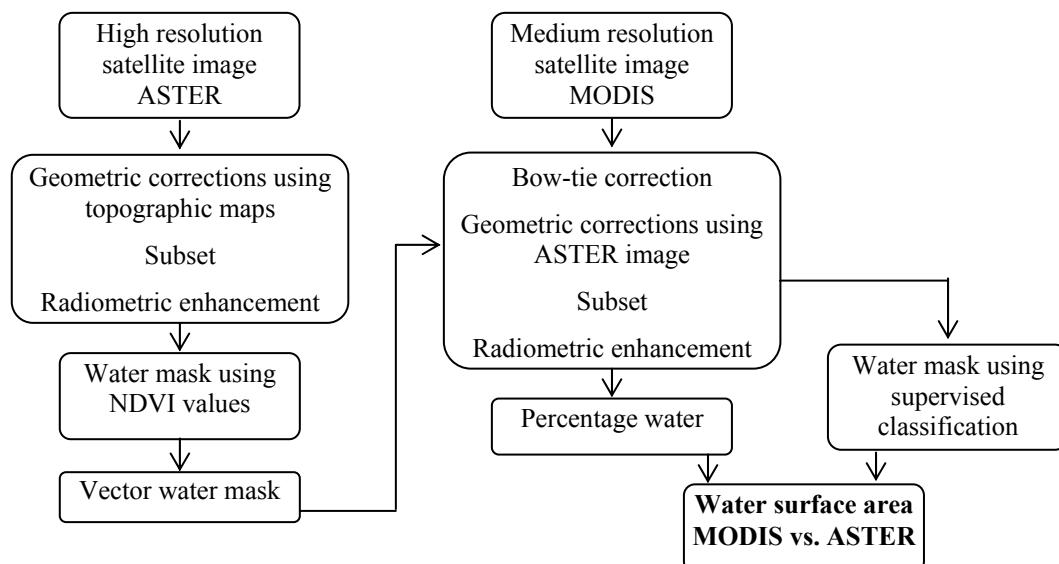
The task was to compare the water area as determined from the ASTER and MODIS water classifications for an identical region on the ground. Since the classification has percentage values, one can not just add up the number of water pixels. The common approach is that each pixel should be multiplied by its percent

water value and then adding them to get the equivalent number of water pixels which can then be multiplied by the area of a pixel. However, one can also make a comparison by finding the average of the percent water pixel values to come up with overall percent water for the area.

ASTER and MODIS data are pre-processed [1], [2] in order to obtain the water cover surface. Both images are imported and geo-rectified in the same projection, using ENVI software image processing. Concerning ASTER image, the Level 1B data imported in ENVI is already projected. VNIR first three bands, at 15 m resolution, were processed. We used MODIS reflectance data from MOD02 Level 1B data. Even the spatial resolution of the 1240 nm Shortwave-IR spectral region band is lower (500 m) as visible bands we preferred to use this too, because of their spectral information valuable in case of sediments present in water. The MODIS image was corrected of the bow-tie effect, which affects these images. We resized the SWIR data for matching with the two visible bands and we created a stack with the three bands at 300 m resolution. The next step was to geo-rectify the data in the Universal Transverse Mercator (UTM) projection, zone 34, datum WGS84. Because of the errors occurred, we used the geo-referenced ASTER image for registering the MODIS data.

In order to delineate the water in the ASTER image, the reflectance feature of water at visible green and absorption feature at NIR were used to map surface water<sup>[3]</sup>, <sup>[4]</sup>. For MODIS image, we tried both a threshold method <sup>[5]</sup> and a supervised classification for water. This last method was performed on the 3-band MODIS image using maximum likelihood algorithm in the spectral overlap area and it seemed to reflect better the water delineation.

The processing algorithm is presented in the figure 1.



**Figure 1: The methodology to compare water classification from MODIS and ASTER satellite images.**

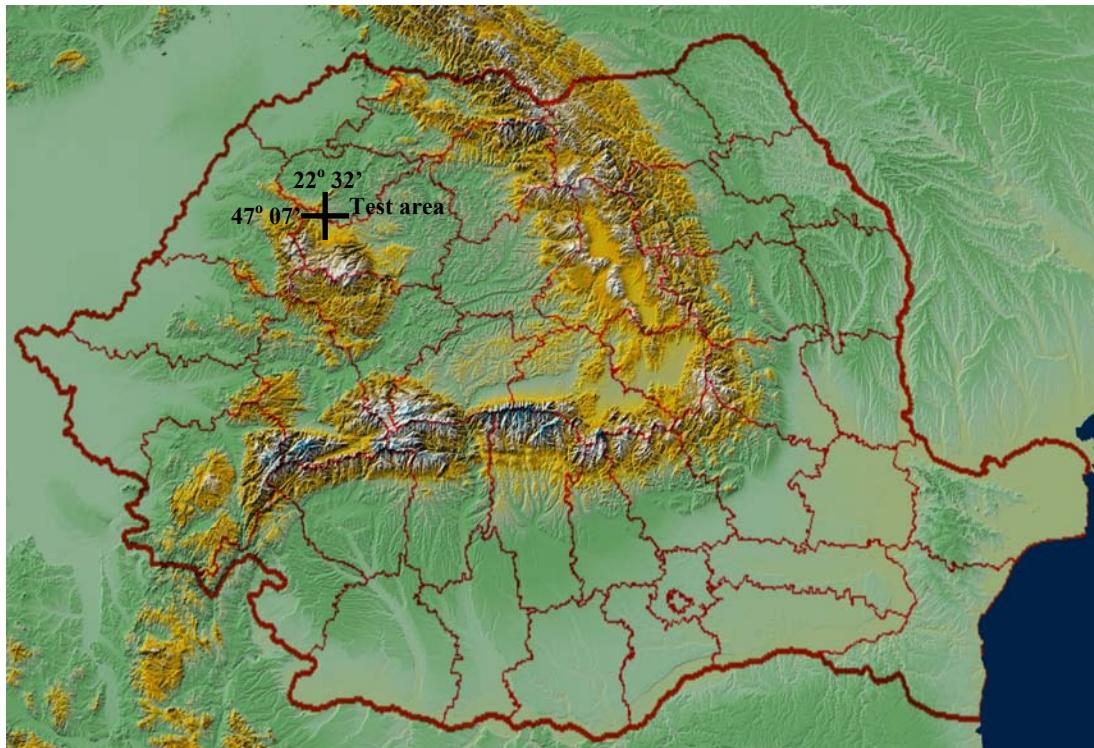
### 3.0 DATA

The study area was located in the Bihor County of Romania (fig. 2). Two lakes were selected and data acquired from TERRA/ASTER (figure 3) and TERRA/MODIS (figure 4) at the site, for October 31, 2002 were chosen.

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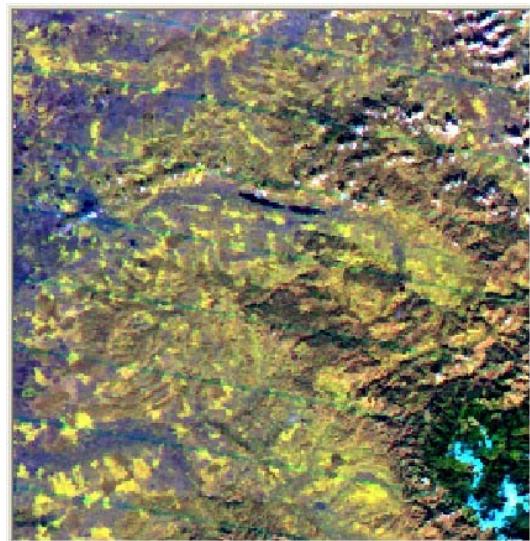
We used visible green, visible red, and Near IR bands of ASTER (bands 1, 2, and 3N), and visible red, Near IR, and Short-Wave (1240 nm wavelength) bands from MODIS (bands 1 and 2 of the 250m resolution data, and the third of the five 500 m resolution bands). The scenes were geo-rectified to UTM projection, with pixel size of 15m for ASTER data and 300m for MODIS data. Figures 3 and 4 show geo-rectified ASTER and MODIS images of the study area. The ASTER image was imported in ENVI image processing software and rotated with the angle 10.43 degrees in order to co-locate and analyzed with MODIS image.



**Figure 2: The study area located in the north-west of Romania.**



**Figure 3: ASTER image of study area.**



**Figure 4: MODIS image of study area.**

## 4.0 RESULTS

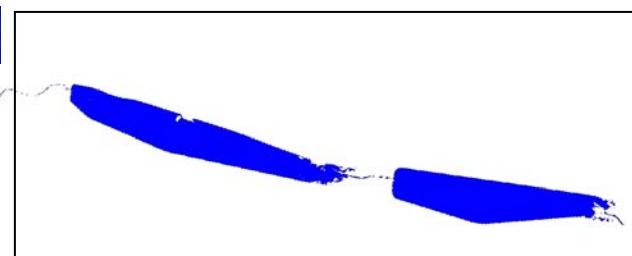
The ASTER data were used to create a detailed water mask to be used as ground truth for the MODIS water classification. From here, a sequence of raster and vector operations comes to compare the two water classifications. Figure 5 shows a more detailed view of the ASTER image, in the lakes region. NDVI (Normalized Difference Vegetation Index) was calculated as the fraction between the difference of the NIR and Red Bands and their sum. ASTER Band 3N and the calculated NDVI (Normalized Difference Vegetation Index) were used to make the water mask (Figure 6), using a formula:  $y = -21x + 72$  (where  $x$  is NDVI and  $y$  is Band 3N). We created an image using this formula and all pixels with the value of 59 or more were called water.

Figure 7 shows a scatter plot of the ASTER data. The dots in the lower left portion of the plot below the straight line are classified as water pixels. The formula was applied only to pixels close to the water bodies as it would not work properly farther away (some pixels would be falsely classified as water).

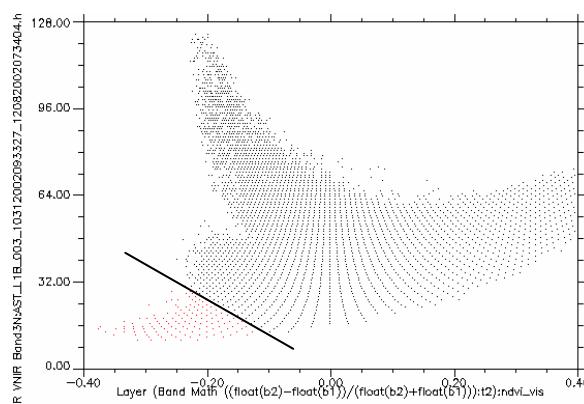
This raster water mask was vectorized and superimposed for comparison on the MODIS water mask obtained by MODIS image processing. A supervised classification for water was performed on the 3 bands MODIS image using the feature space algorithm, with maximum likelihood algorithm used in the spectral overlap area (Figure 8). The “degrade” function in ERDAS Imagine was used on the binary water versus not water 15 m ASTER mask to estimate the percentage of water in each MODIS pixel classified as water. Next figure (figure 9) represents the two masks, obtained from ASTER and MODIS data. In the figure 10 the percent water image derived from ASTER was superimposed on the MODIS image. Finally, the ASTER and MODIS water delineation were overlaid and we calculated the differences between the pixels classified as water, both in ASTER and MODIS images.



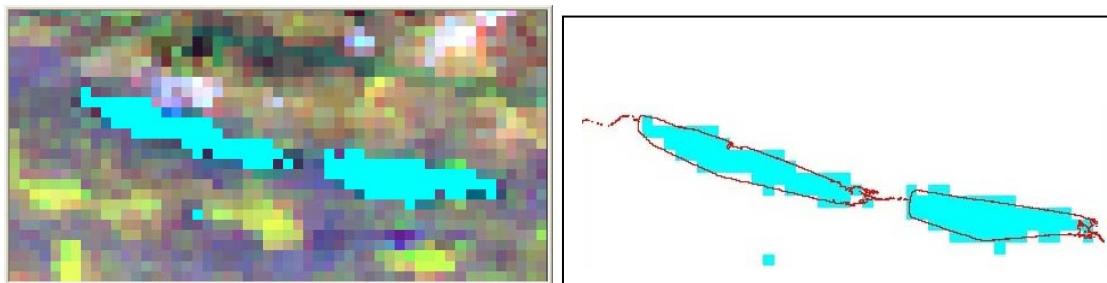
**Figure 5: Detailed ASTER image of study area.**



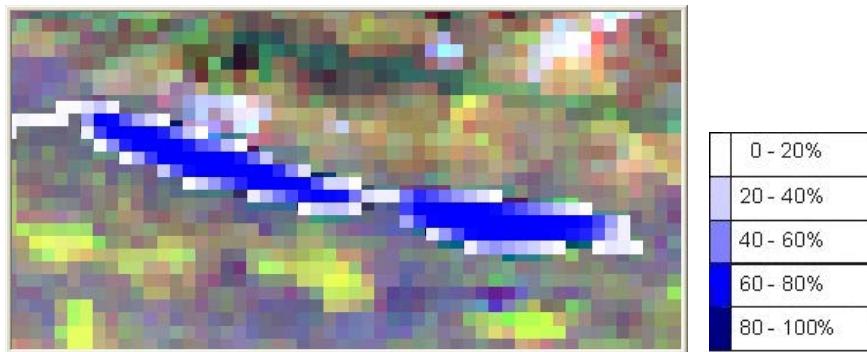
**Figure 6: Water mask created from ASTER data.**



**Figure 7: Scatter plot of ASTER data - water pixels are in lower left part of image, below the line.**



**Figure 8: Water mask created from MODIS data. Figure 9: MODIS water classification and ASTER-derived water mask.**



**Figure 10: Percentage water ground truth (in blue tones) created by "degrading" ASTER water mask and superimposed on MODIS image and the legend of water pixels.**

The water surface area as measured from the MODIS classification was 981.5 hectares, about 16% more than the ASTER ground truth-value of 847.6 hectares and this difference represents the incorrect classification of “border” pixels in MODIS image.

## 5.0 CONCLUSIONS

The overall goal of this paper was to classify MODIS data to get an estimate of water surface area. To develop the classification technique, the strategy was to obtain MODIS and ASTER data acquired at the same time over the same location, and use the ASTER data as “ground truth”. Since MODIS pixels are large compared with many water bodies, it was useful to determine the fraction of a MODIS pixel covered with water, rather than just binary water versus not-water distinction. This approach gives us useful information concerning the water classification from different resolution data that could help in the estimation of water surface area from MODIS imagery. In the future, we plan to use the MODIS classification as a water mask, and create a percentage of water area for each pixel within the mask, based on a MODIS band, NDVI, or other band combination.

## AKNOWLEDGEMENTS

This research was supported by the National Meteorological Administration (Romania) and Dartmouth Flood Observatory, Hanover, New Hampshire, as part of the NATO Science for Peace Programme, Project no. 978016 “Monitoring of Extreme Flood Events in Romania and Hungary Using Earth Observation (EO) Data”.

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